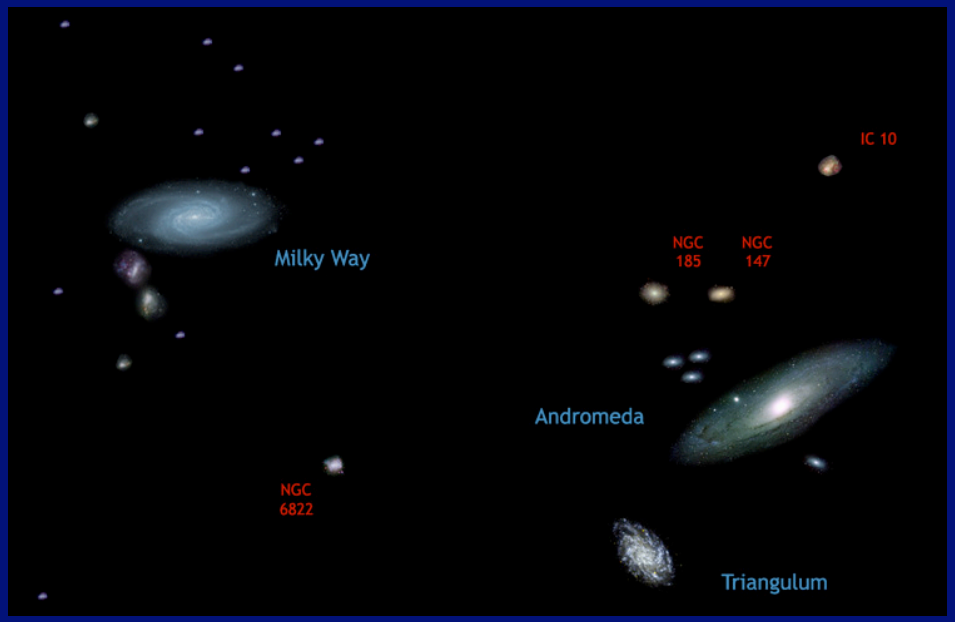
Origin and Evolution of Structure and Nucleosynthesis for Galaxies in the Local Group

X. Zhao, G. Mathews and L. Nguyen
CANDU/JINA University of Notre Dame



Cosmic Chemical Evolution Workshop June 2-4, 2010 St. Michaels, MD

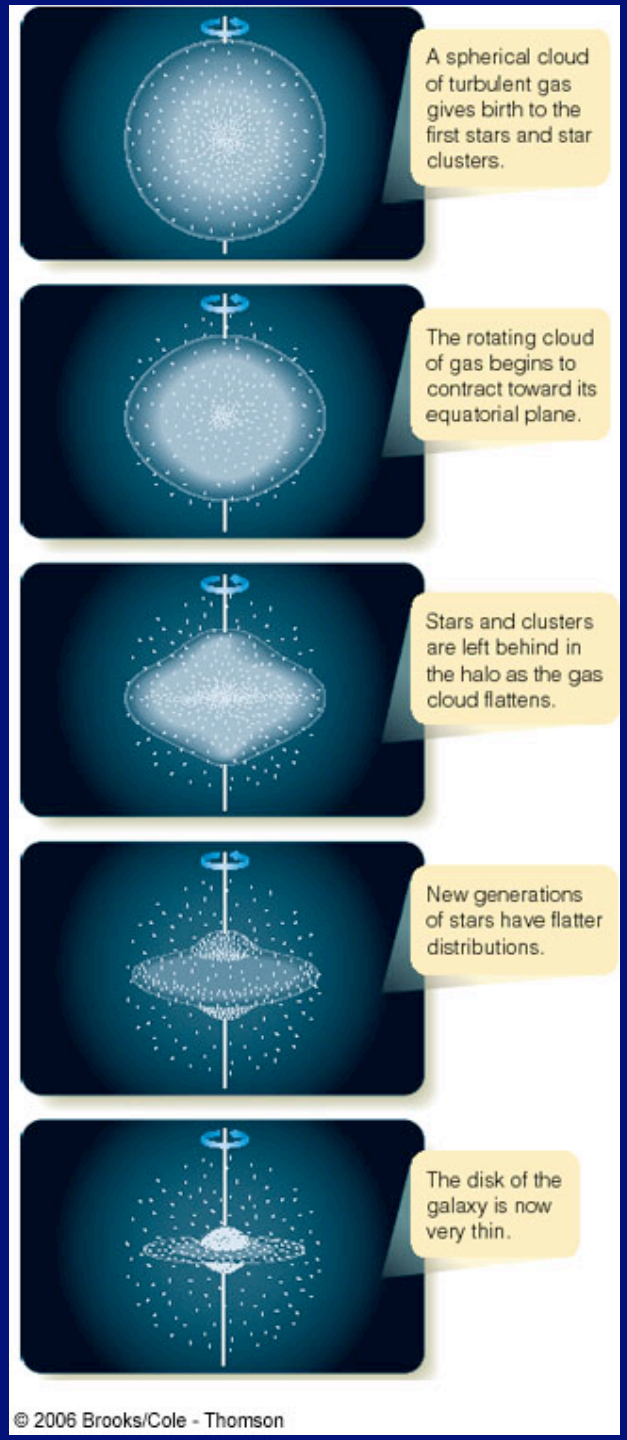
Goals of GCE Models

- Explain the distribution of stellar and ISM elemental abundances vs. kinematic properties, location, ages

- Use these to explain the properties of the Galaxy and external galaxies along with how they formed and evolved

Goal in this Work:

Obtain a realistic simulation of the formation of the Milky Way and other members of the Local Group and study the evolution of the abundance during this process



History of the Milky Way

The traditional theory:

Quasi-spherical gas cloud fragments into smaller pieces, forming the first, metal-poor stars (pop. II, III);

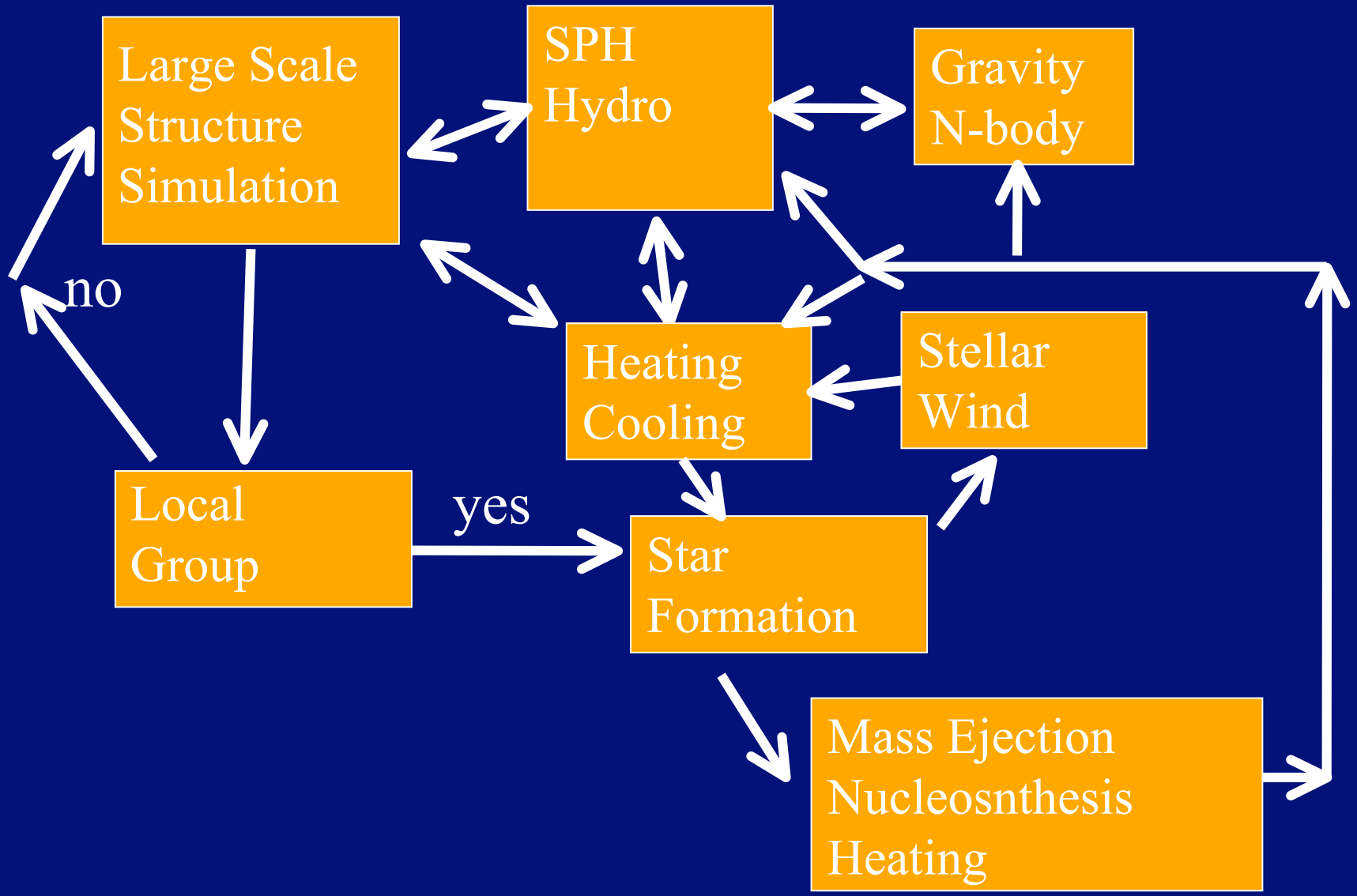
Rotating cloud collapses into a disk-like structure

Later populations of stars (pop. I) are restricted to the disk of the galaxy

Present View:

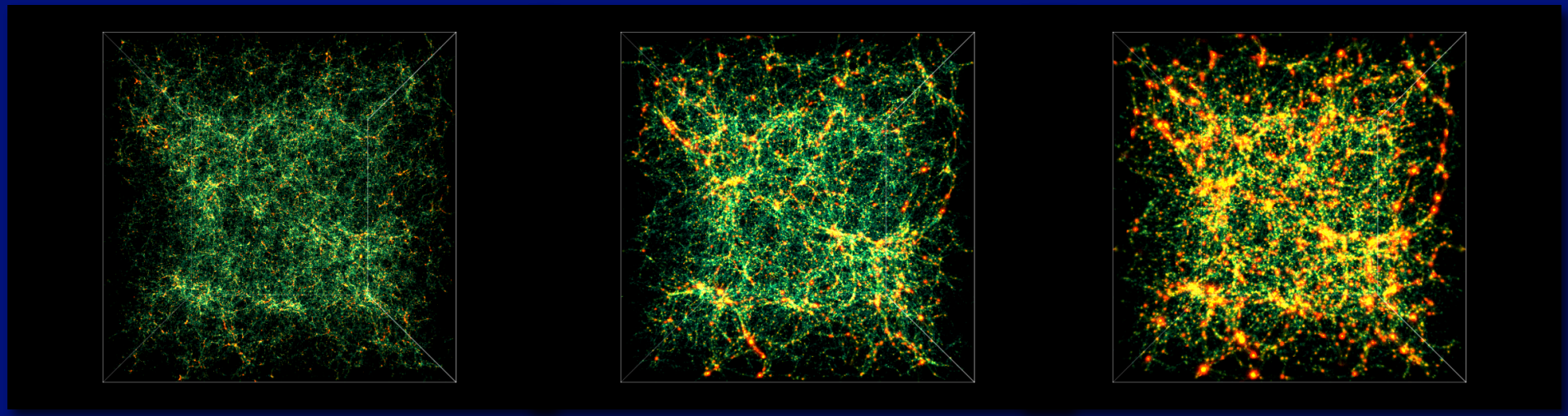
- The Galaxy did not form in isolation.
- It is the product of the development of much larger structure.
- It was formed in concert with the entire Local Group and was affected by star formation and nucleosynthesis processes occurring throughout a large volume.

Virtual Local Group



Details of the Numerical Simulation

We adopted the N-body Smoothed Particle Hydrodynamics (SPH) code GADGET-2 (Springel, 2005). The simulations were set up with the Grafic packages (Bertschinger, 2001) and IC package (Sirko, 2005) combined with the CMBFAST code (Seljak and Zaldarriaga, 1996).



Ω_m=0.3 Ω_Λ=0.0

Ω_m=0.3 Ω_Λ=0.7

Ω_m=1.0 Ω_Λ=0.0

$$\frac{D\rho}{Dt} + \rho\nabla\cdot\mathbf{v} = 0$$

$$\frac{D\mathbf{v}}{Dt} = -\frac{1}{\rho}\nabla P - \nabla\Phi$$

$$\frac{Du}{Dt} = \frac{P}{\rho^2}\frac{D\rho}{Dt} + \frac{\nabla\cdot(\kappa\nabla T)}{\rho} + \frac{\Gamma-\Lambda}{\rho}$$

$$\nabla^2\Phi = 4\pi G\rho$$

SPH method

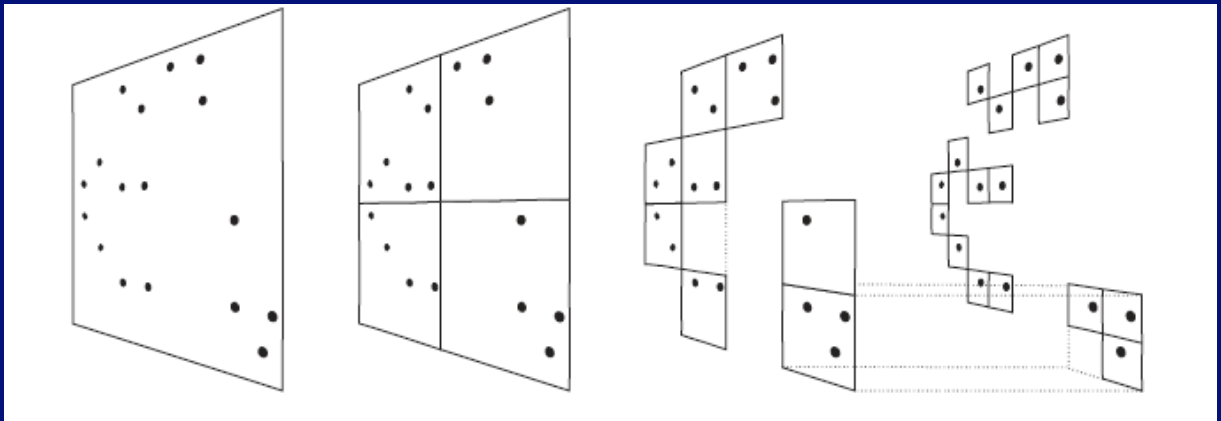
$$\rho_i = \sum m_j W(\mathbf{r}_i - \mathbf{r}_j; h)$$

$$\frac{D\mathbf{v}_i}{Dt} = -\sum m_j\left(f_i\frac{P_i}{\rho_i^2}\nabla_i W_{ij}(h_i) + f_j\frac{P_j}{\rho_j^2}\nabla_i W_{ij}(h_j)\right) - \sum m_j\Pi_{ij}\nabla_i\overline{W}_{ij}$$

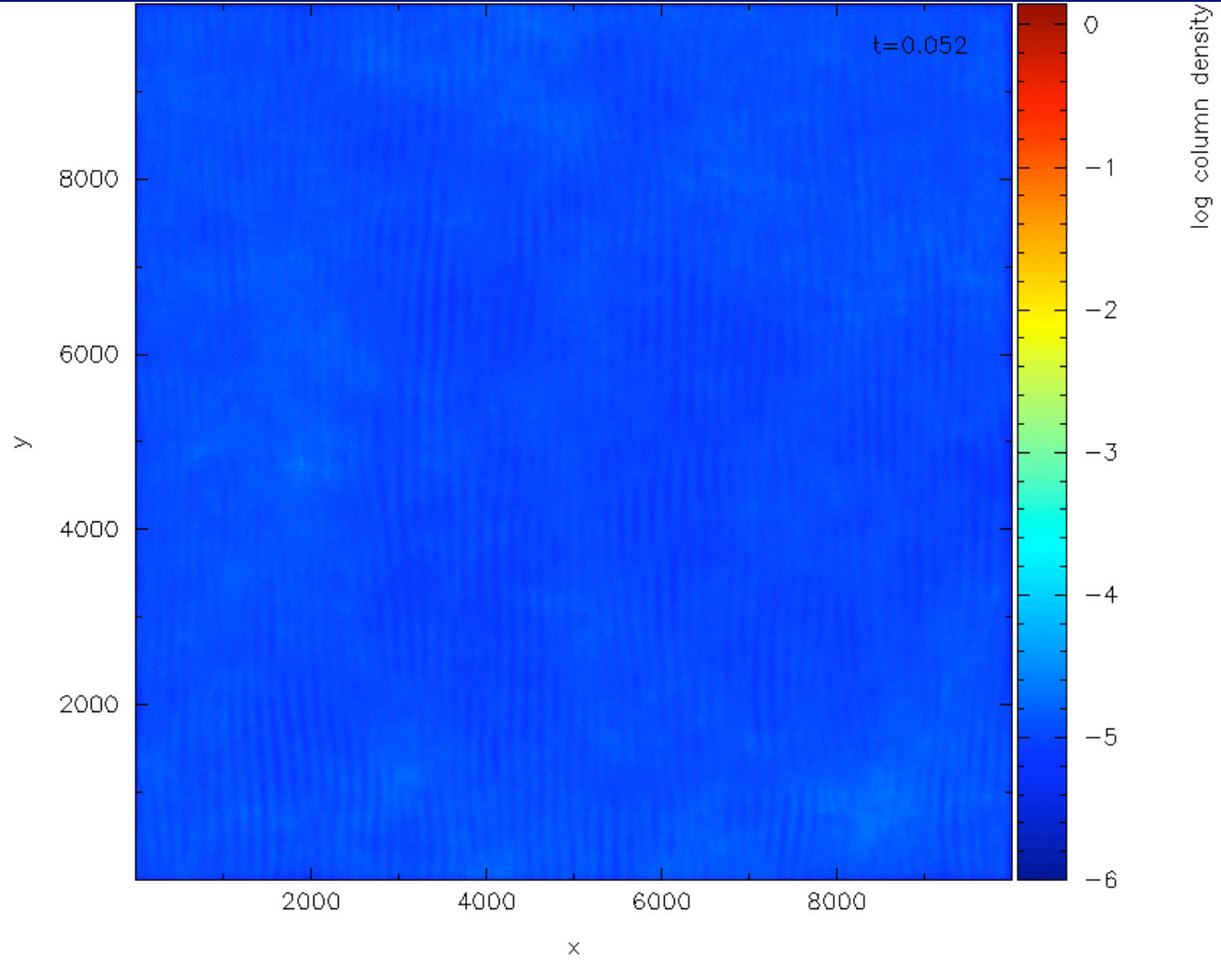
$$\frac{DA_i}{Dt} = \frac{1}{2}\frac{\gamma-1}{\rho_i^{\gamma-1}}\sum m_j\Pi_{ij}\mathbf{v}_{ij}\cdot\nabla_i\overline{W}_{ij} + \frac{\gamma-1}{\rho_i^{\gamma}}(\Gamma-\Lambda)$$

Smoothed Particle Hydrodynamics

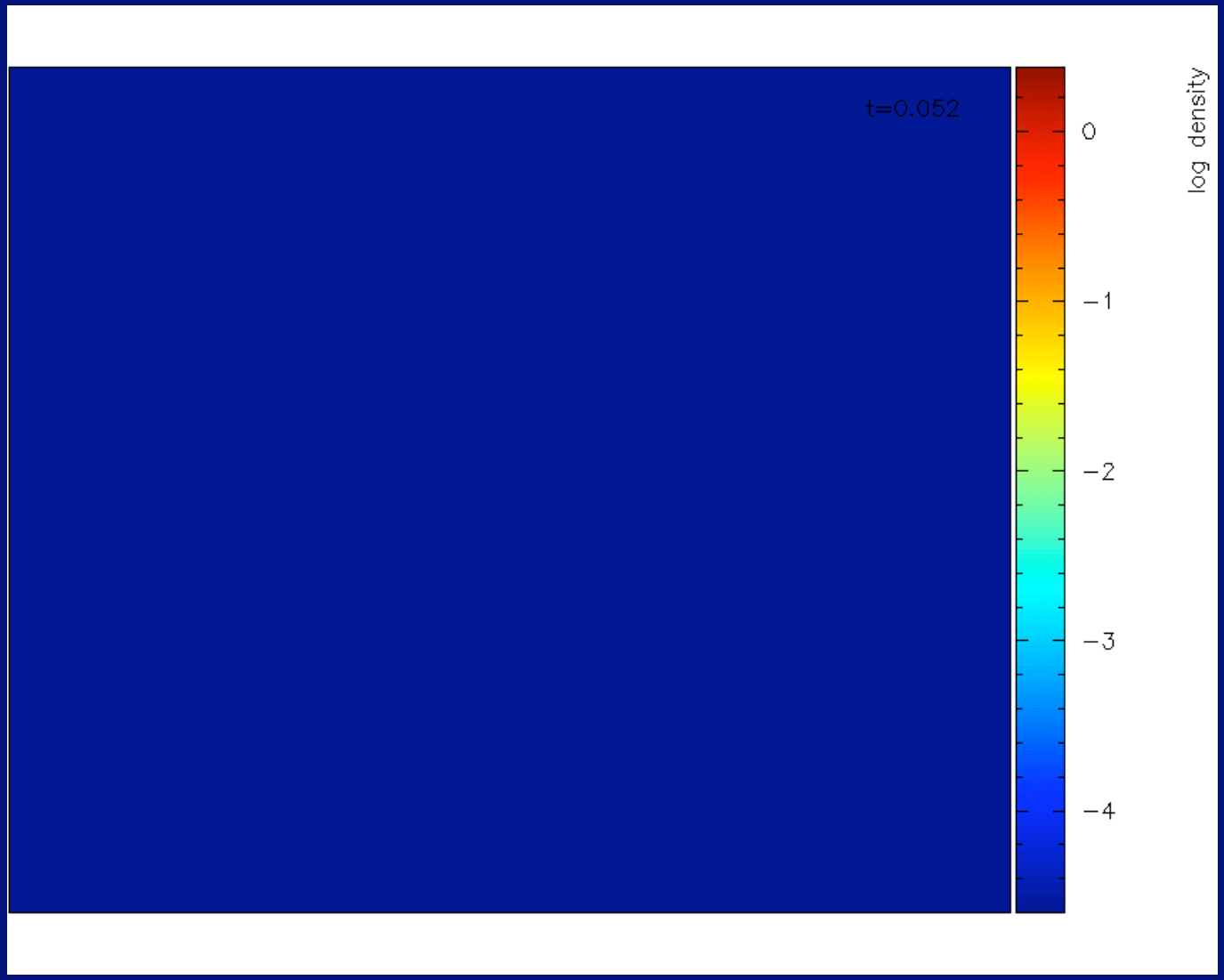
Gravity Tree Algorithm

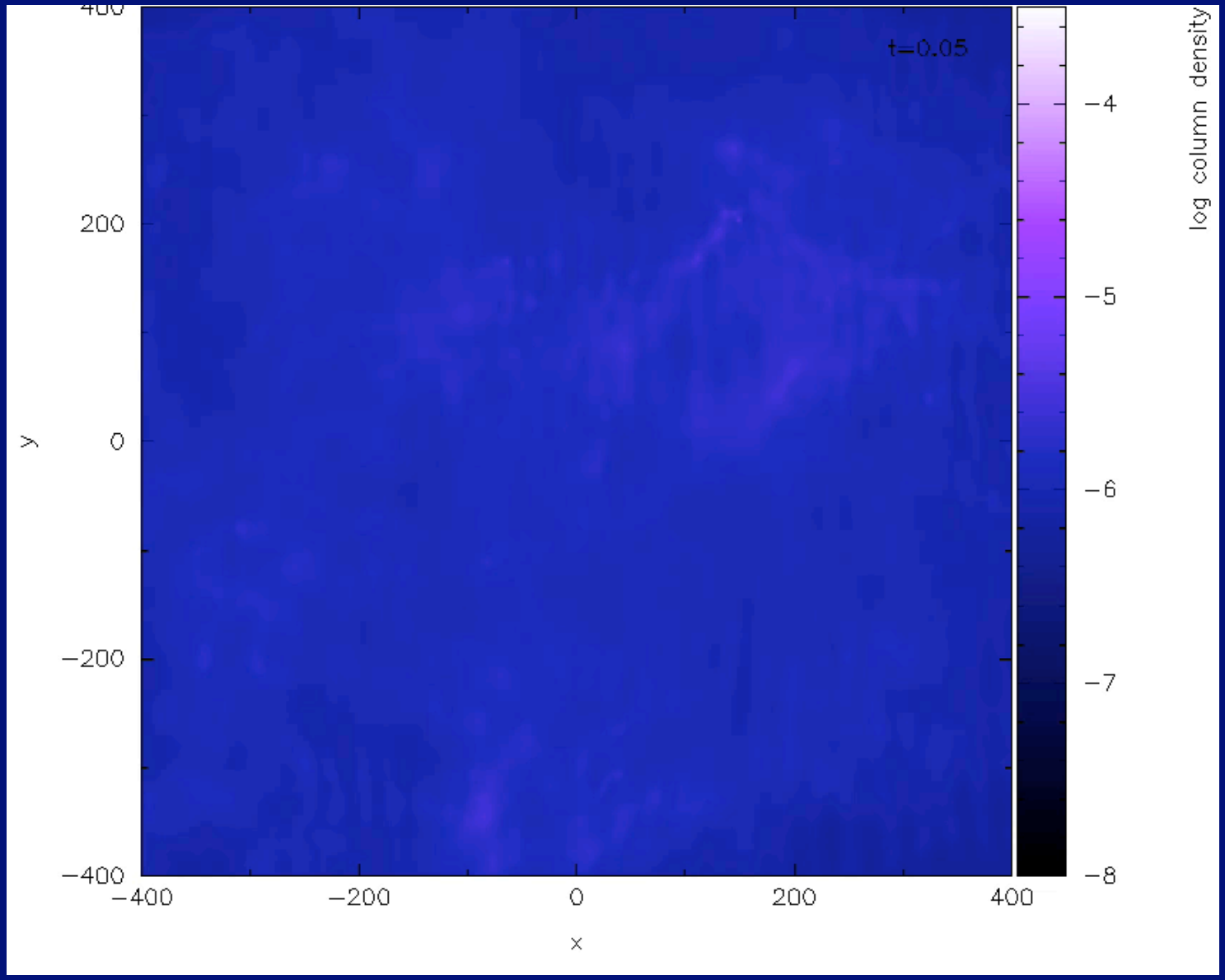


The simulation

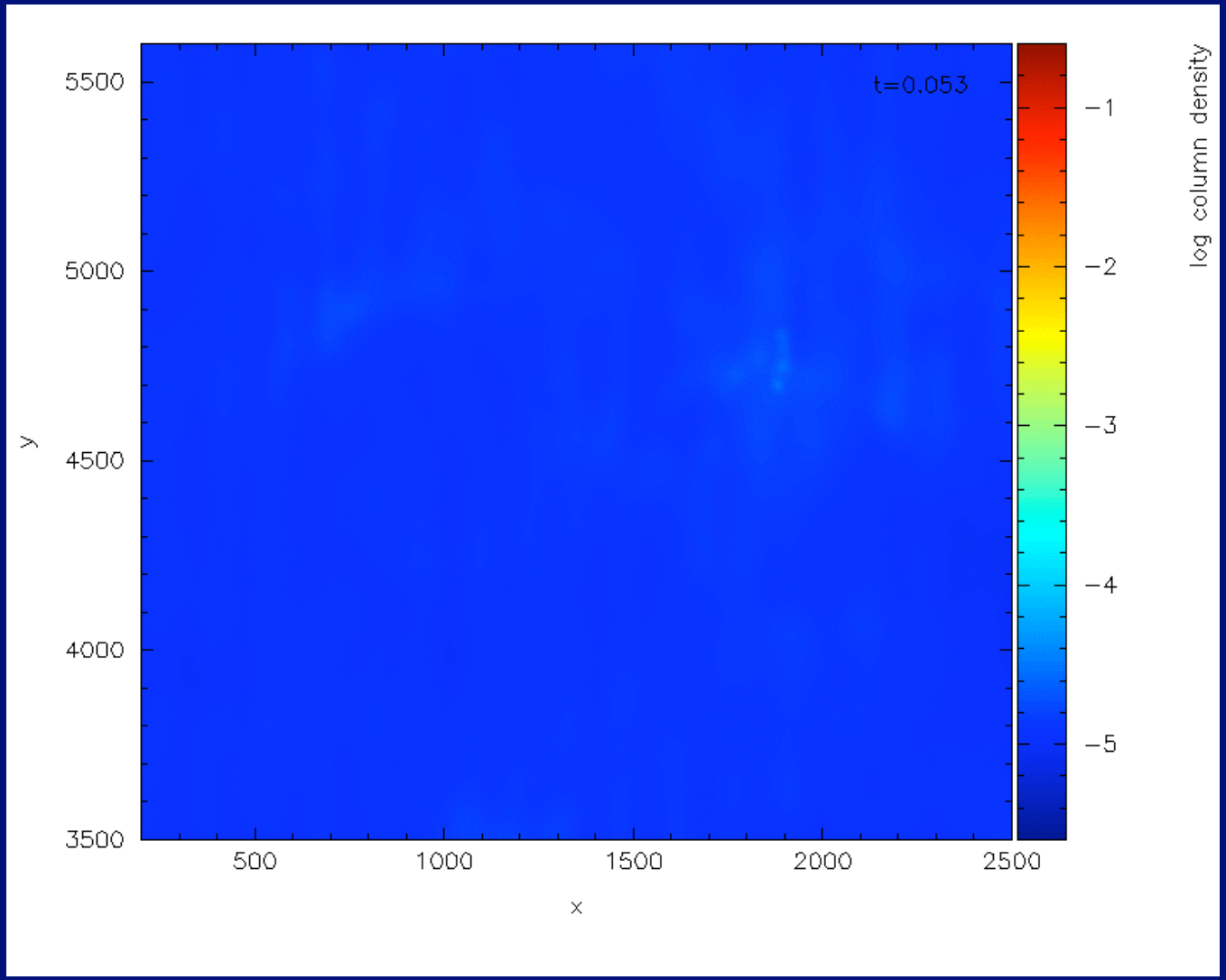


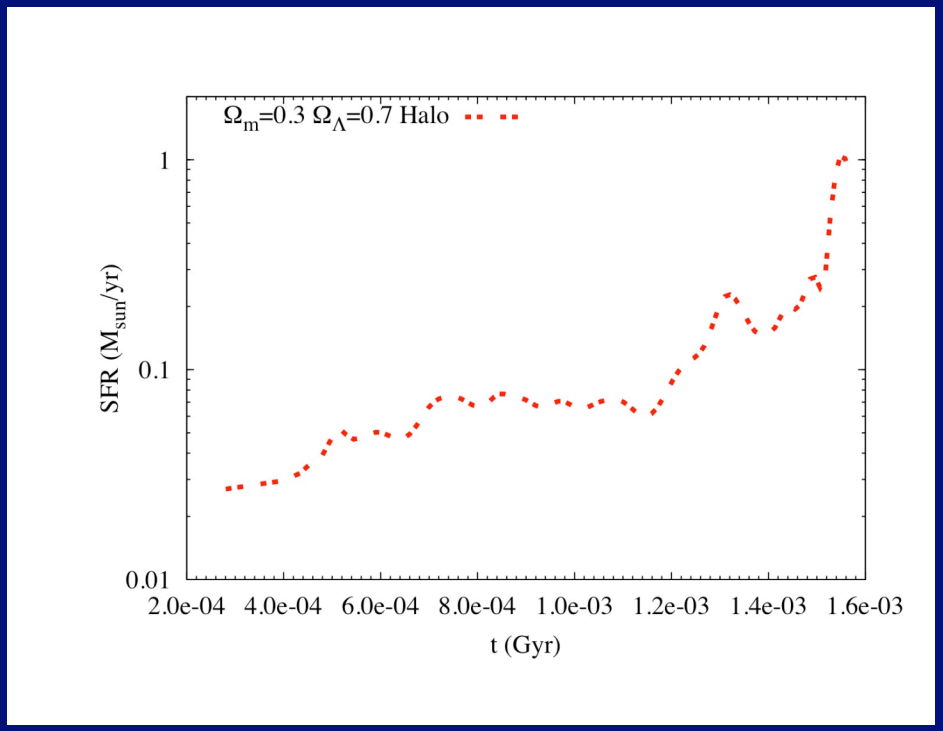
Mpc scale zoom

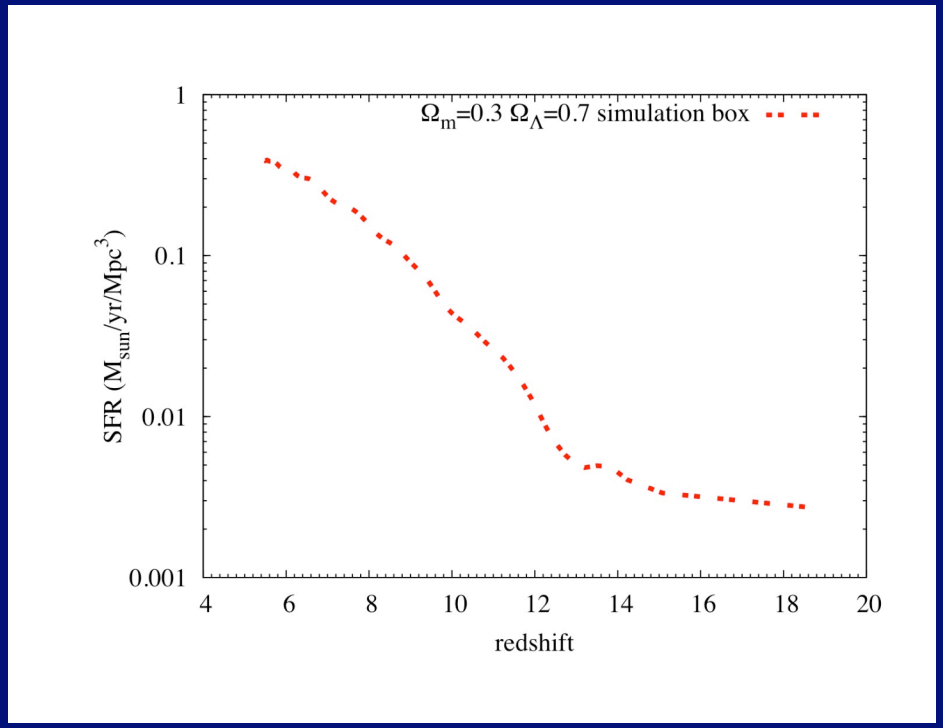



t=0.05
log column density
−4
−5
−6
−7
−8
y
400
200
0
−200
−400
−400
−200
0
200
400
x

Early Results




Ω_m=0.3 Ω_Λ=0.7 Halo
SFR (M_{sun}/yr)
1
0.1
0.01
2.0e-04
4.0e-04
6.0e-04
8.0e-04
1.0e-03
1.2e-03
1.4e-03
1.6e-03
t (Gyr)


Ω_m=0.3 Ω_Λ=0.7 simulation box
SFR (M_{sun}/yr/Mpc^3)
1
0.1
0.01
0.001
4
6
8
10
12
14
16
18
20
redshift

Summary

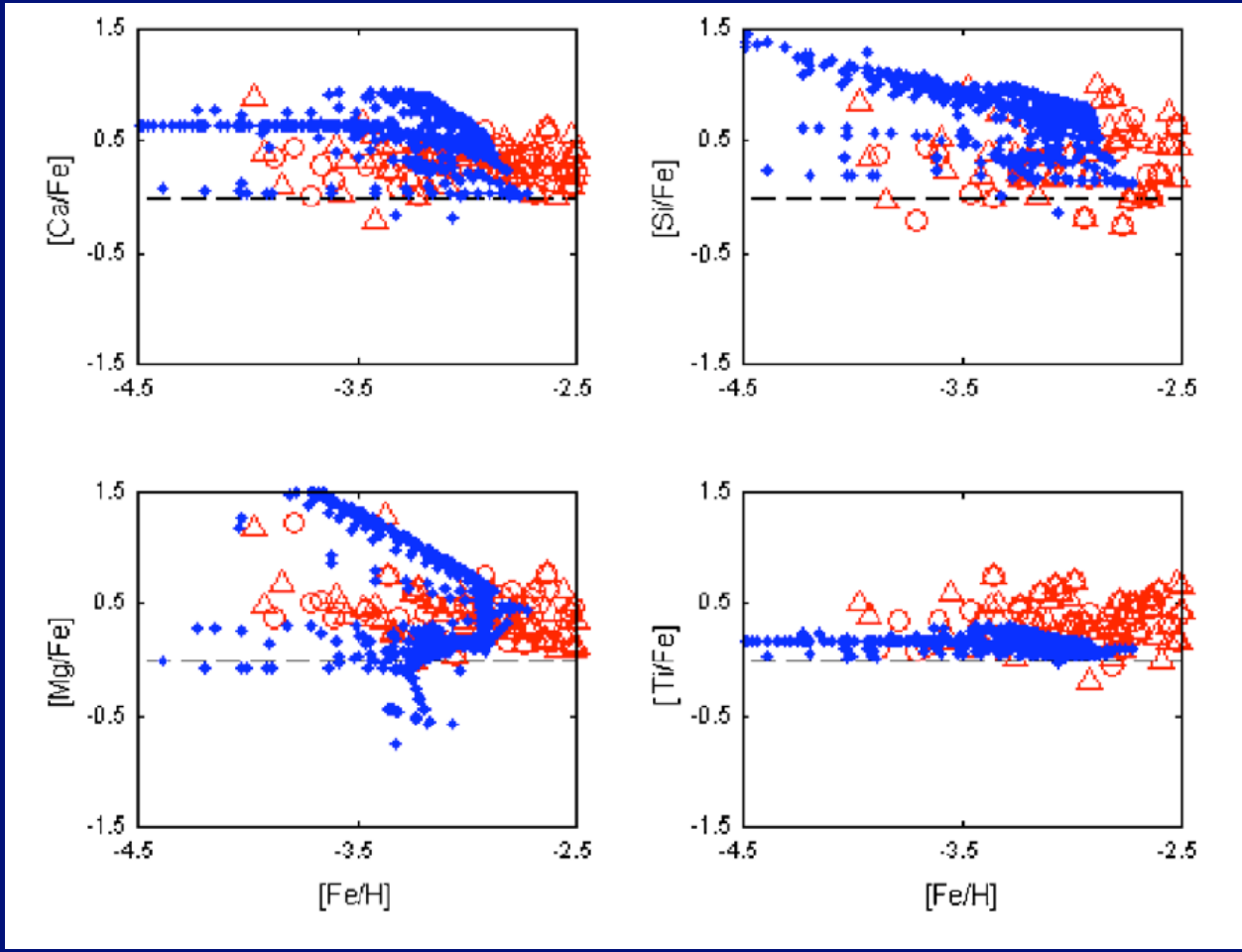
•Galaxies are not isolated objects but are the culmination of halo formation, mergers, star formation and nucleosynthesis in an extended connected environment.

•Significant star formation and nucleosynthesis occurs far from the galaxy in protogalactic structures.

•Protogalactic halos that arrive in a stochastic stream flowing along dark-matter filaments.

•There should be a distribution of kinematic and metallicity distributions in the halo

Next Step: Reconstruct Abundance vs Metallicity Relations for different stellar populations



Saleh, Beers, Mathews (2006)